Flexural-isostatic reconstruction of the Western Mediterranean vertical motions after the Messinian Salinity Crisis Implications for sea level and basin connectivity

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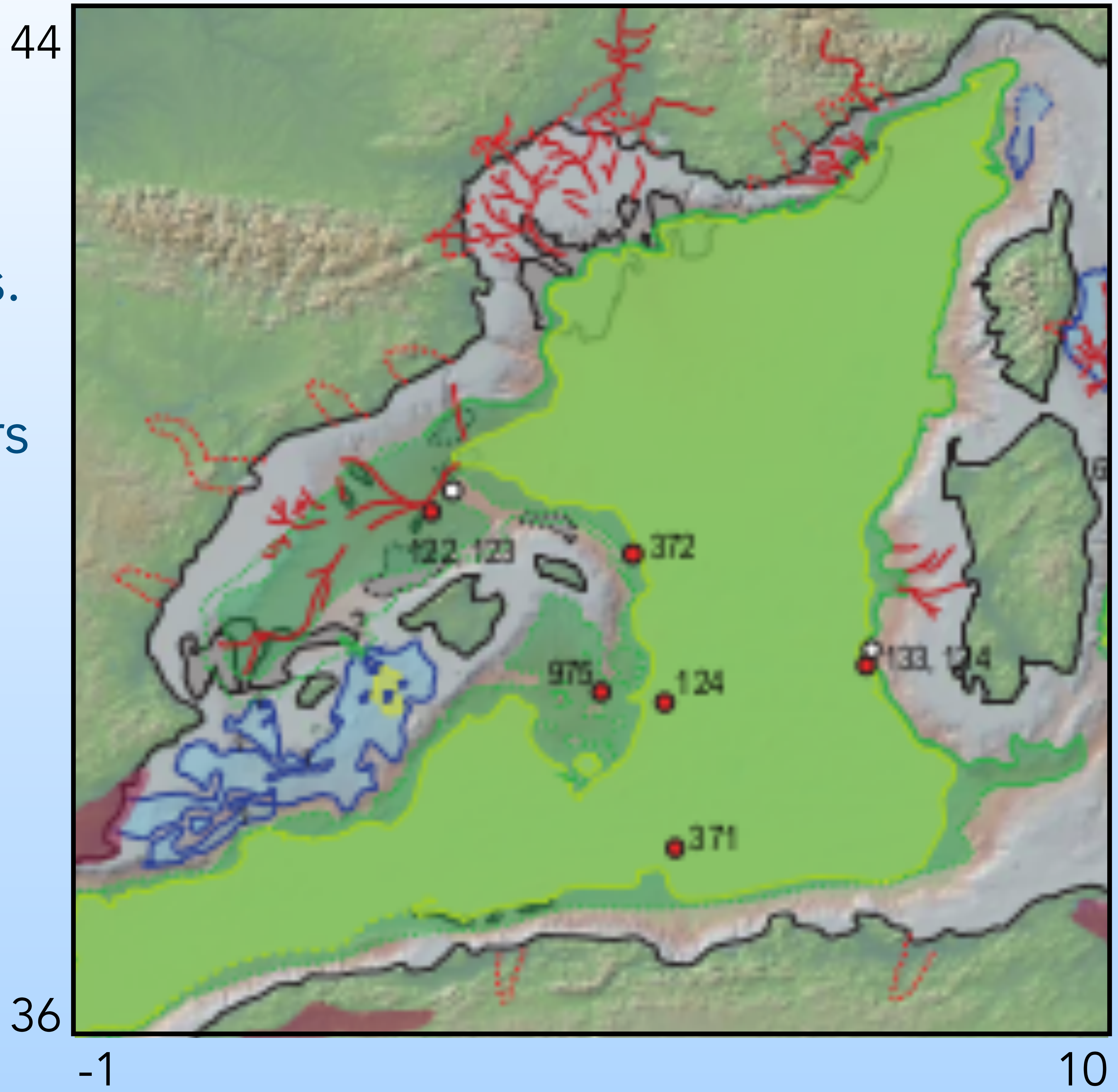
Objectives

- Messinian Salinity Crisis - 5.97-5.33 Ma, ~5% of global ocean salt sequestered in 3-stage km-scale evaporites, extensive incision of fluvial canyons and erosion or margins.

- What was the ***original*** vertical position of Messinian markers in the Western Mediterranean?

- What magnitude of sea-level drop is required to obtain shoreline positions observed in seismic stratigraphic record?

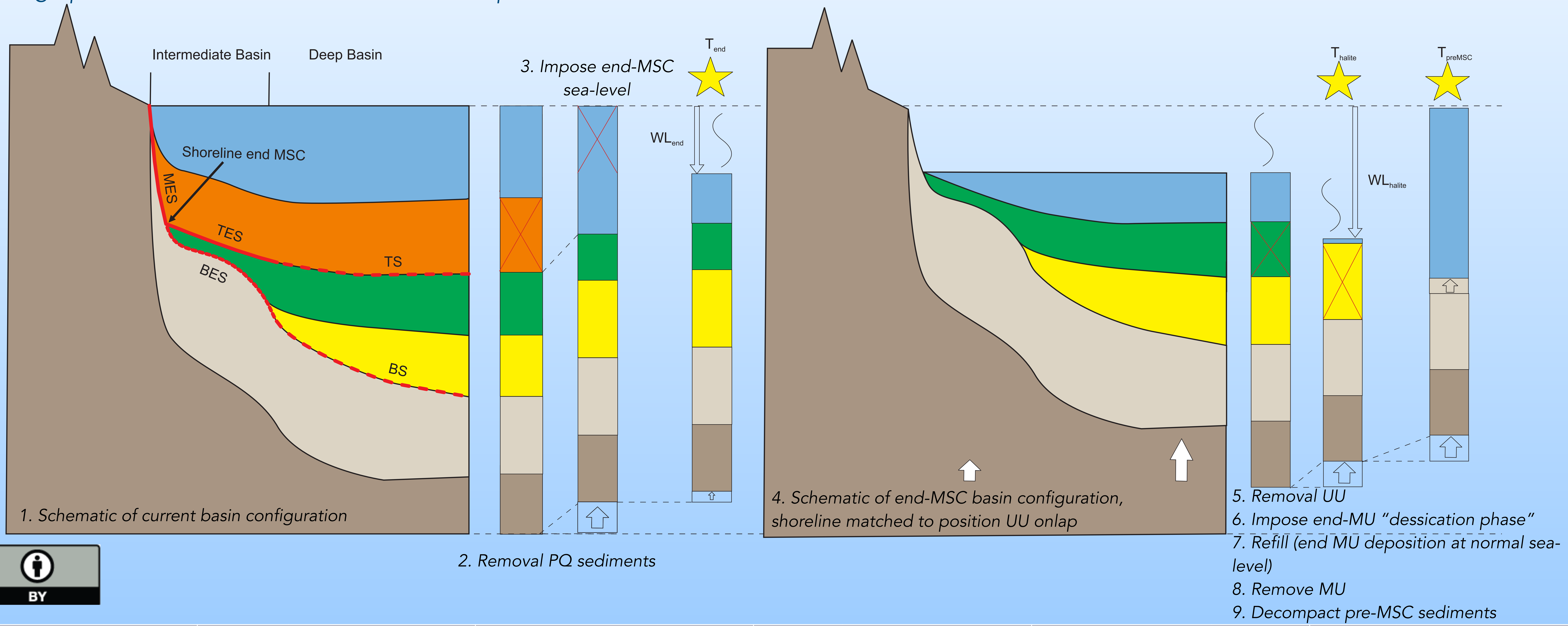
- Were Messinian evaporites deposited at normal water levels or during lowstand? Were (sub)basins connected during deposition?



Detail from extension map of the MSC seismic markers in the Western Mediterranean, showing Mobile Unit (yellow), Upper Unit (green), and Complex Unit (blue) distributions, from: Seismic Atlas of the Messinian Salinity Crisis markers in the Mediterranean Sea - Volume 2 (Lofi et al., 2018)

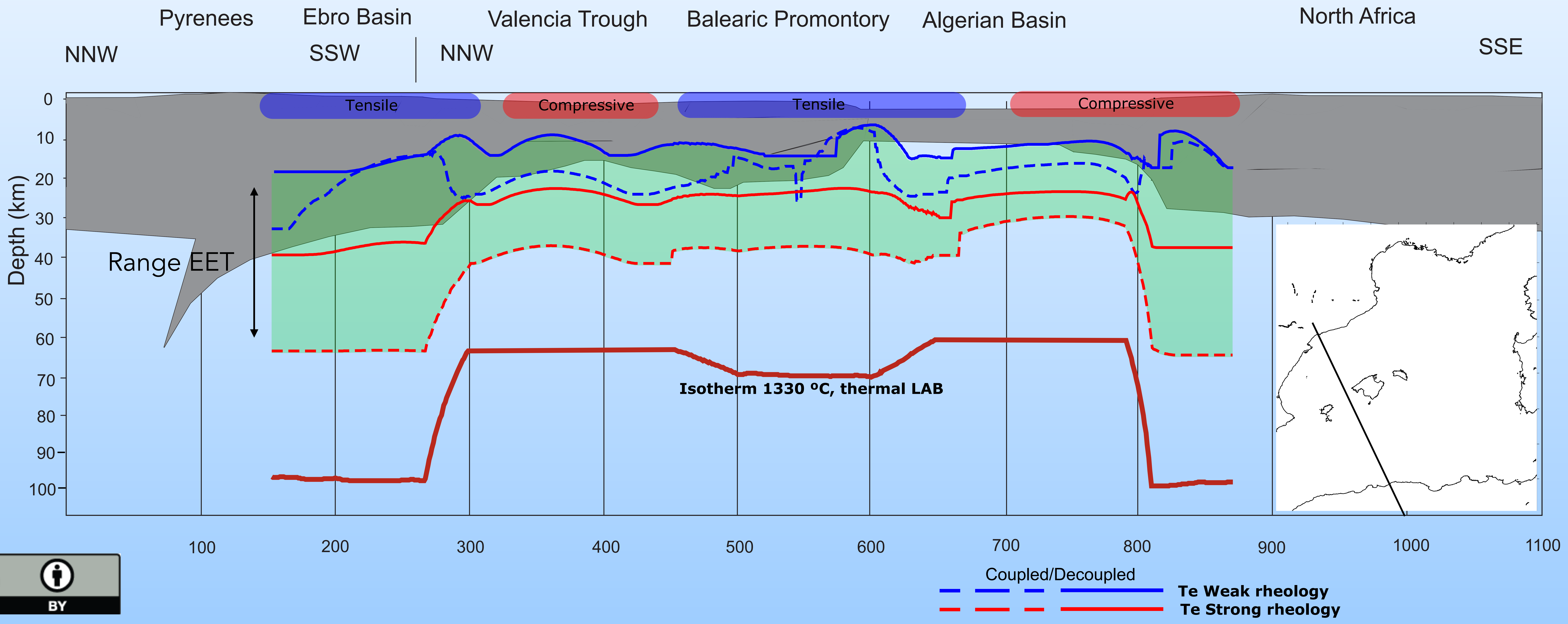
Methods

- Flexural-isostatic modelling in pseudo-3D (map view) using TISC (Garcia-Castellanos et al. 2003)
- Step-by-step backstripping, imposing sea level drop to match observed paleo shorelines. *Crucial is extent of erosional contacts in seismic stratigraphic record, and their subaerial vs. subaqeus nature!*



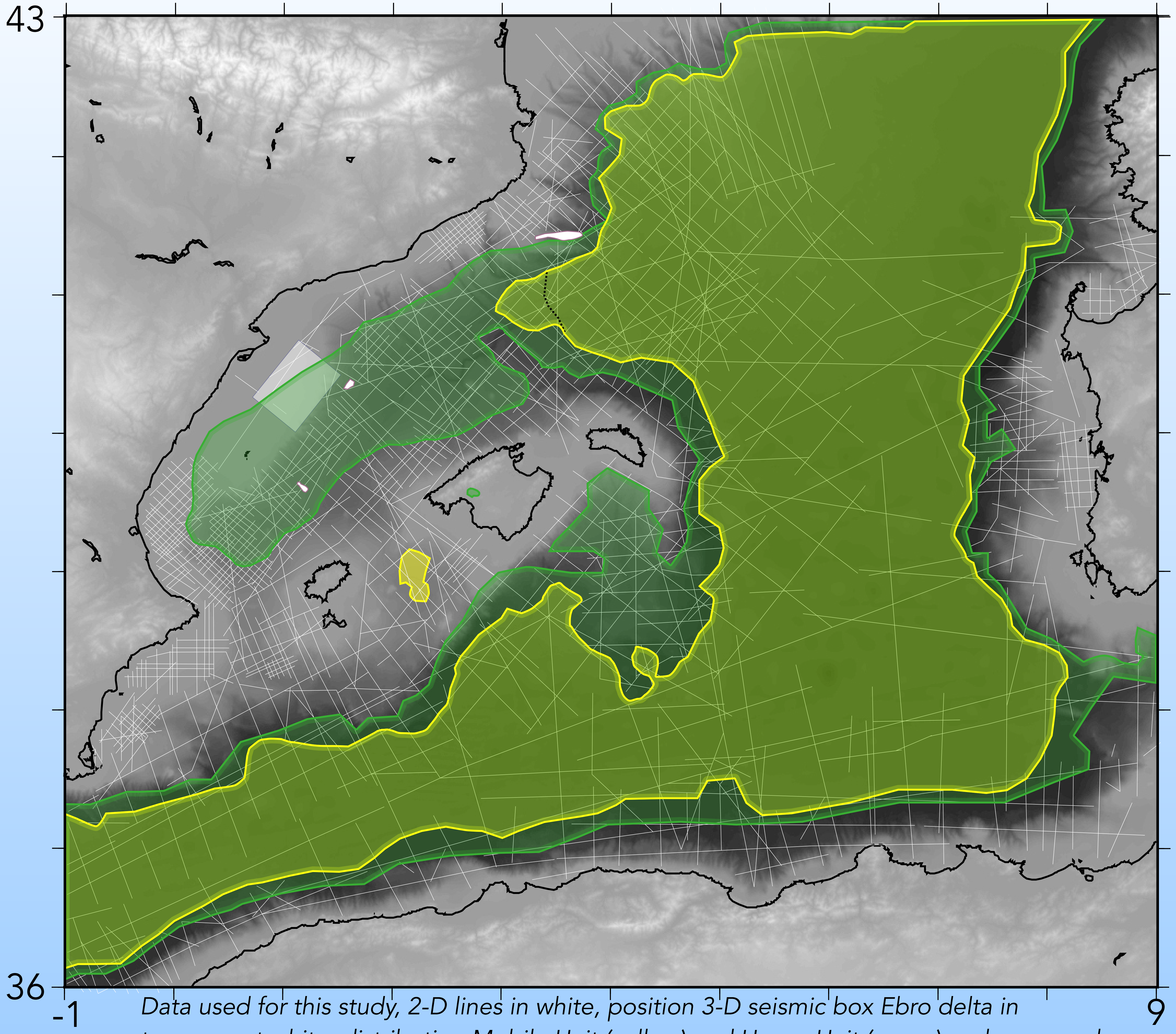
Methods

- 2-D flexure model (tAo) combining thermal and material property variations (Carballo et al., 2015) + load stresses along Iberia-Algeria profile to obtain estimate of Effective Elastic Thickness in region. Values of 10 and 45 km used for sensitivity analysis.



Data

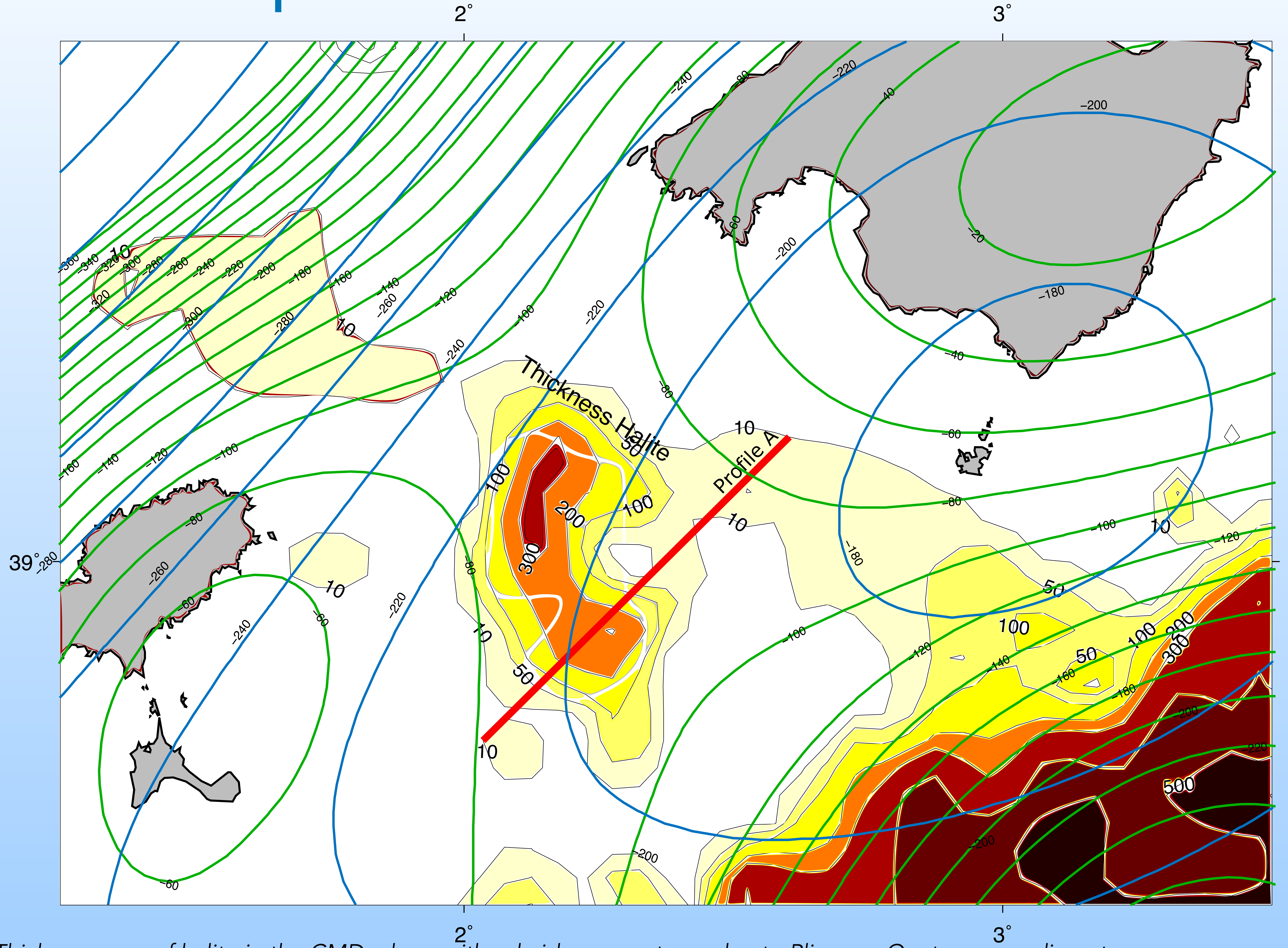
- Comprehensive database of vintage and industry 2D seismic data (e.g. Maillard et al., 2014, Camaselle&Urgeles, 2017), plus 3D cube in Ebro delta (Urgeles et al., 2010)
- Partially reinterpreted to obtain accurate basement depth and distribution of MSC markers on Balearic Promontory



Data used for this study, 2-D lines in white, position 3-D seismic box Ebro delta in transparent white, distribution Mobile Unit (yellow) and Upper Unit (green) and proposed extent Basal Erosion Surface under Mobile Unit from Maillard et al., 2006 (dashed)

Central Mallorca Depression (CMD)

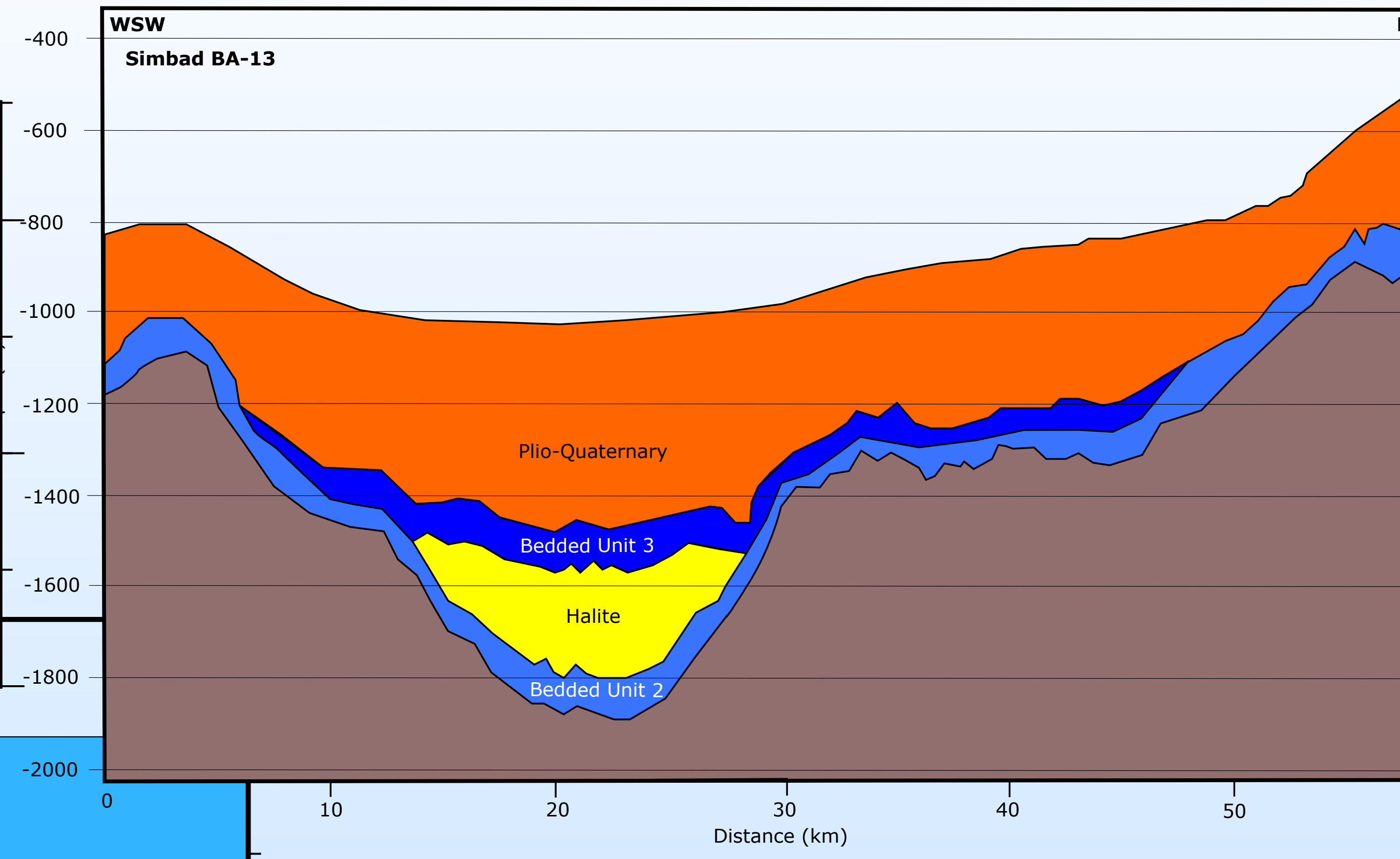
- Unique example of halite in intermediate depth basin. Was this connected to the deep basin during deposition?
- Halite in CMD reaches thickness of 300 m.
- Current depth top halite at ~1300 m.
- Deflection due to Pliocene-Quaternary sediments in CMD ranges from 90 m (EET = 10 km) to 200 m (for EET = 45 km)
- Strong lithosphere results inconsistent with modern elevation Messinian Carbonates on Mallorca



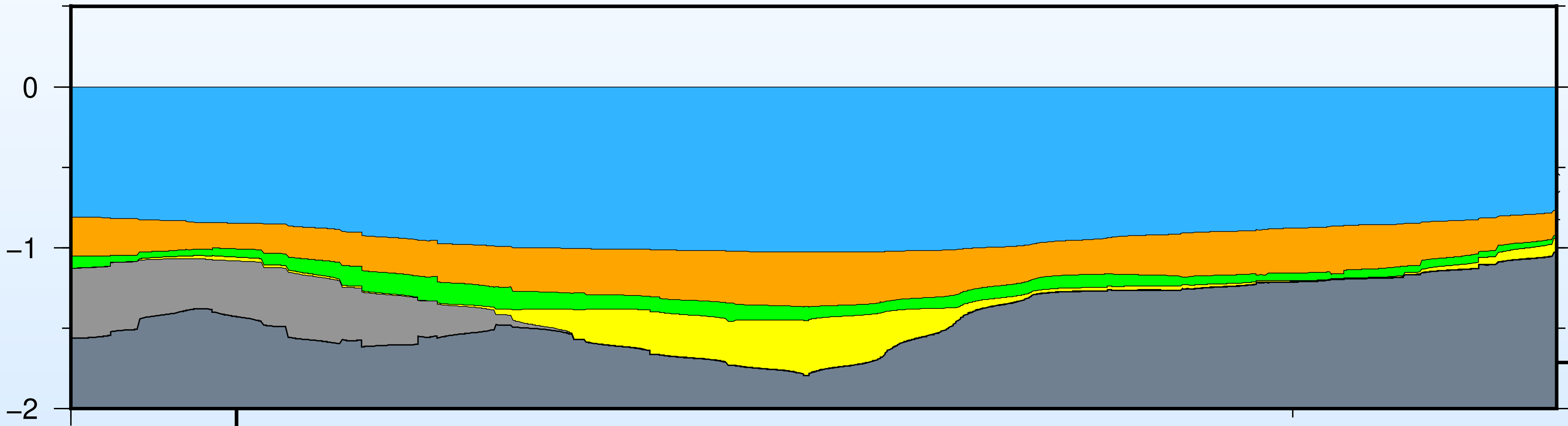
Thickness map of halite in the CMD, along with subsidence contours due to Pliocene-Quaternary sediments (blue for EET= 45 km, green for EET = 10 km)

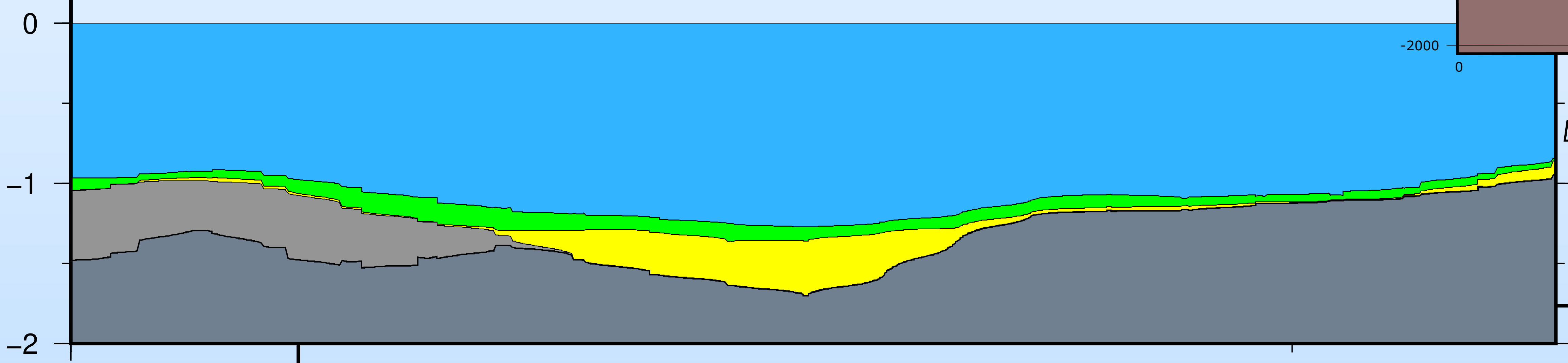
Central Mallorca Depression

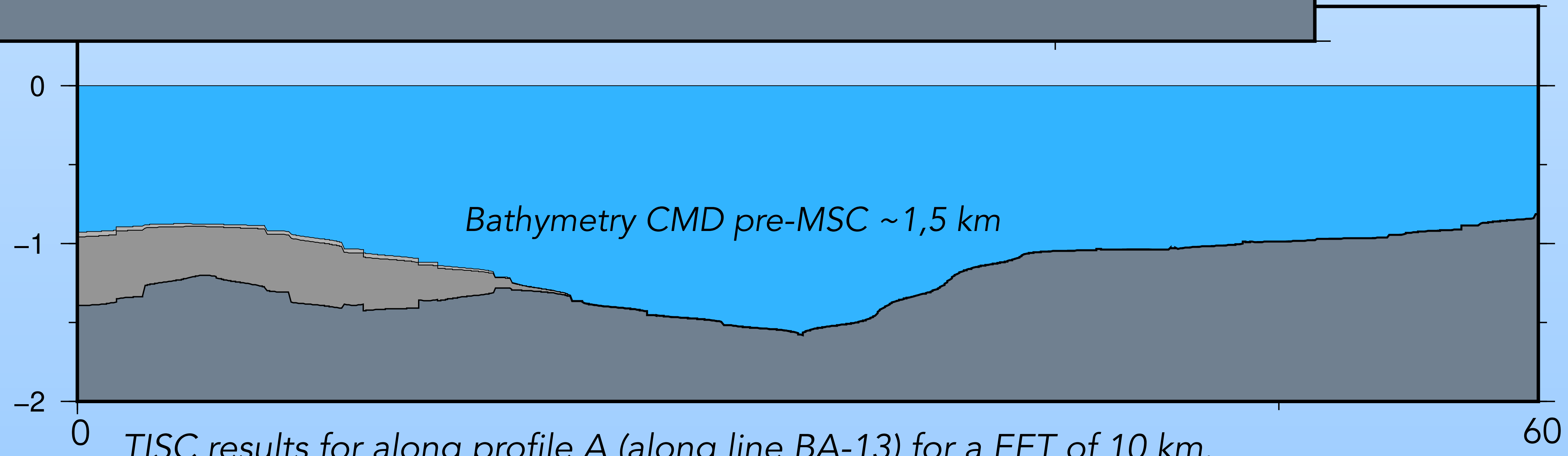
- Seismic line Simbad BA-13
- Bathymetry at the end of Halite deposition ~1200 m.
- End-halite drawdown of ~800 m enough to isolate CMD from surrounding basins.
- Ratio paleowaterdepth/halite thickness CMD and deep basins very similar. (1km/300 m and 3 km/1000m respectively)



Depth-translated interpretation line BA-13 (by Fadl Raad)



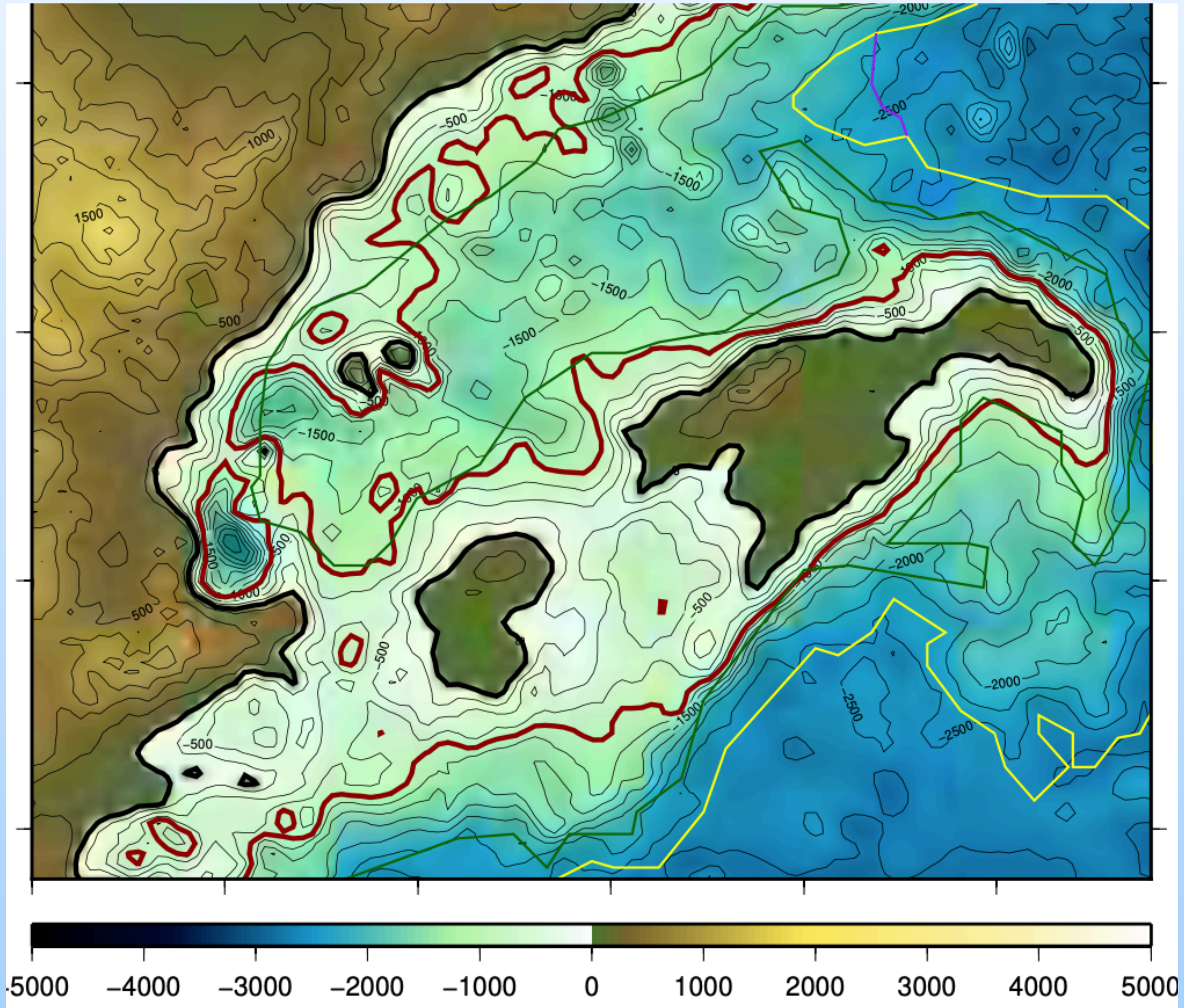




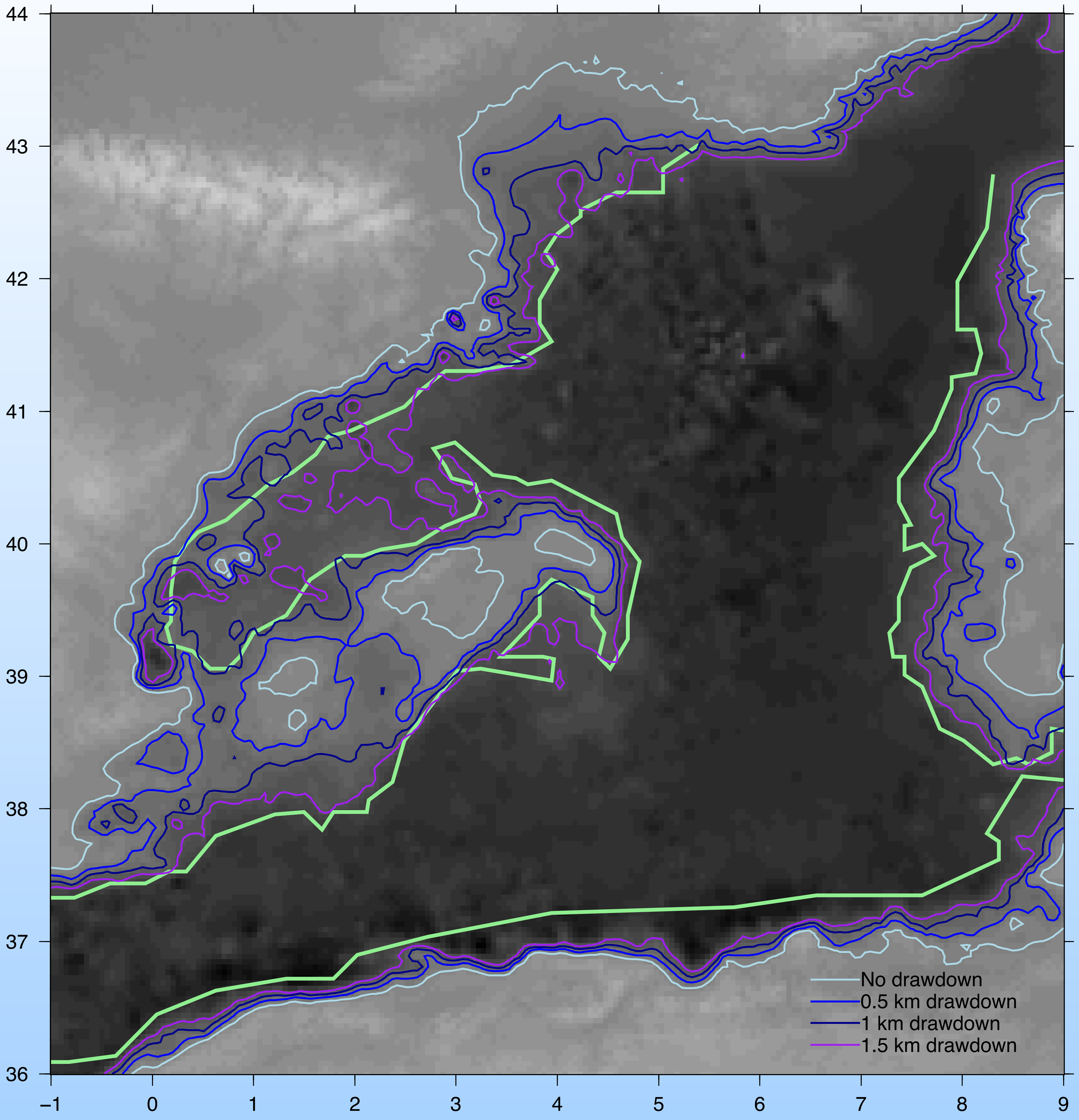
TISC results for along profile A (along line BA-13) for a EET of 10 km.
A) Current, B) End MSC after reflooding, C) End halite deposition, D) pre-MSC

Valencia Basin

- ~1 km water level at end MSC best fit for onlap UU in Valencia Basin and Ebro Delta.



Topography and shoreline (dark red) in the Valencia trough and Balearic Promontory at the end of the MSC (before flooding) with water levels at -1km



Sensitivity of shoreline position to different sea-levels at the end of the MSC for an EET value of 10 km. Onlap Upper Unit in green.

Conclusions

1. Preliminary results indicate sea level ~1 km below modern required to match only of Upper Unit - Margin Erosion Surface boundary.

2. If 2-step refill is assumed, along with subaerial nature of Bottom Erosion Surface in Valencia Trough, initial drawdown after Mobile Unit deposition could have been as high as ~2 km.

3. CMD would have been isolated by a drawdown of ~800 m, so halite must have been deposited at high water levels, and thicknesses of halite in CMD and deep basins hint at direct relationship depth water column and accumulation rate.

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